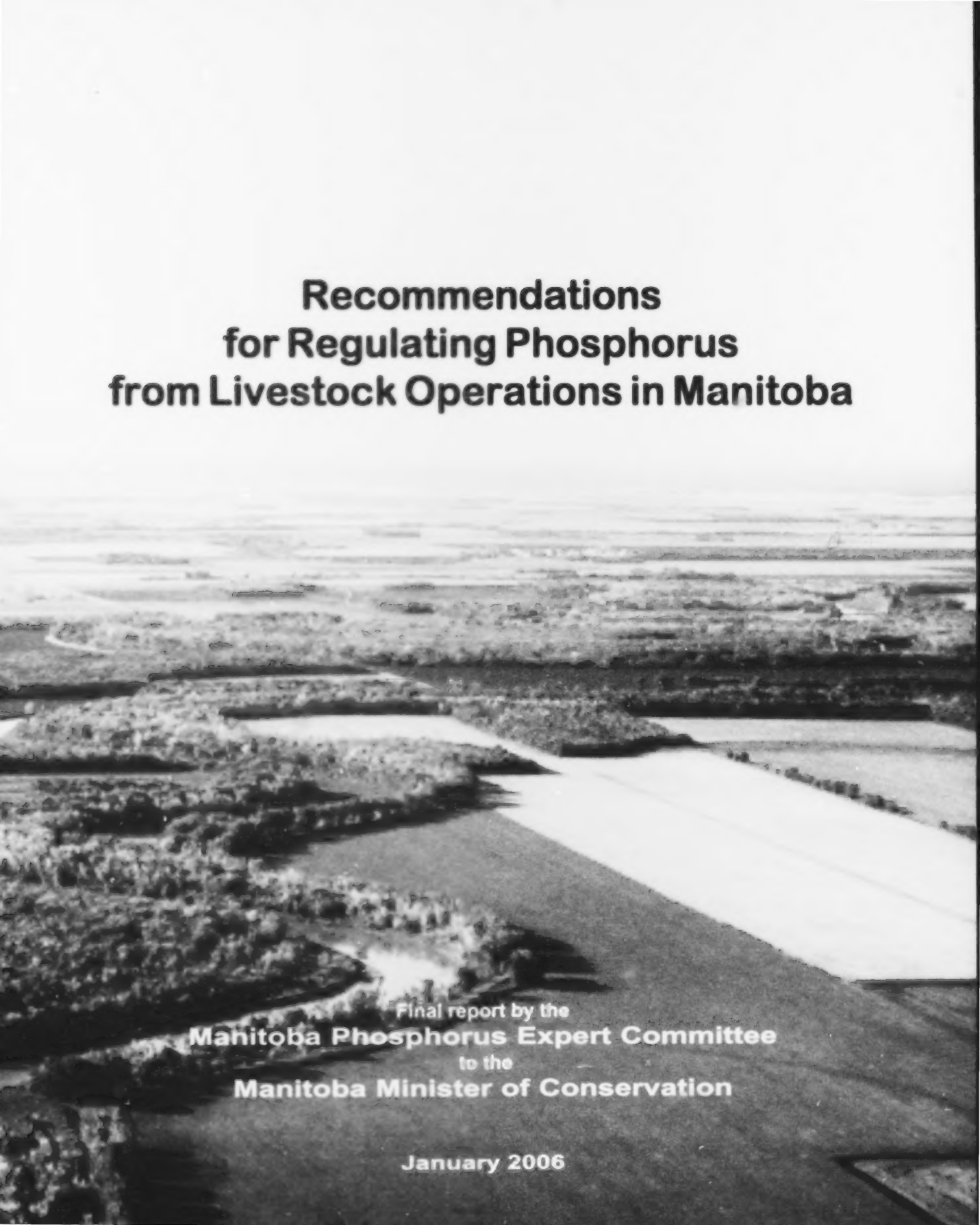
Recommendations for Regulating Phosphorus from Livestock Operations in Manitoba



Final report by the

Manitoba Phosphorus Expert Committee

to the

Manitoba Minister of Conservation

January 2006

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Executive Summary

The primary concern surrounding phosphorus in Manitoba is the eutrophication of waterways and water bodies, and in particular, Lake Winnipeg. While there are many sources of phosphorus – natural and man-made – a particular concern exists related to the land application of manure, and its potential impact on phosphorus in Manitoba soils and in surface waters.

In September 2002, the Minister of Conservation established the Manitoba Phosphorus Expert Committee (MPEC, the Committee) to examine the issues surrounding phosphorus and livestock manure.

The primary purpose of the Committee was to propose alternate strategies, regulatory or otherwise, that may be more effective in Manitoba for managing manure-phosphorus in a way that does not unduly limit crop and livestock production while increasing safeguards against overloading watercourses with crop nutrients. To meet its mandate, the MPEC sought information from several sources including existing reports, input from specialists and experts in the field, and through a review of programs, regulations, and policies from other jurisdictions.

The Committee has concluded that the focus for regulating phosphorus in Manitoba should be to minimize the risk of phosphorus loss to surface water by reducing excessive phosphorus loading onto land and minimizing the mobilization and delivery of phosphorus to water. The Committee has decided that the most promising approach to regulating the land application of phosphorus is to use soil test phosphorus threshold ranges to trigger a change in management.

The Committee has recommended using soil test phosphorus threshold ranges to trigger a change in management.

The environmental risk associated with elevated soil phosphorus concentrations arising from livestock manure applications should be managed through incrementally restrictive requirements for use of phosphorus at different thresholds of soil test phosphorus. Four ranges of soil test phosphorus thresholds are proposed and imply an increasing degree of restriction for land application of livestock manure based upon the soil's phosphorus content. These are described in the associated recommendations.

Recommendation 1.0: Soil test phosphorus thresholds

1.1 For soil test phosphorus concentrations of less than 60 parts per million (ppm), no restriction on phosphorus application is required. Livestock manure may be applied based on crop nitrogen requirements.

2.2 For soil test phosphorus concentrations of 60 to 119 ppm, efforts must be made to control phosphorus accumulation in the soil profile. Livestock manure may be applied based on a rate up to two times the rate of crop removal of P_2O_5.

2.3 For soil test phosphorus concentrations of 120 to 179 ppm, further increases in phosphorus in the soil profile must be controlled. Livestock manure may only be applied at a rate up to one times the crop removal rate of P_2O_5.

2.4 For soil test phosphorus concentrations of 180 ppm or more, efforts must be made to reduce the amount of phosphorus in the soil profile. Livestock manure may not be applied without the written consent of the Director.

There are geographic areas within Manitoba that require special consideration when implementing management strategies to mitigate the risk of phosphorus loss. These Special Management Areas (SMAs) in Manitoba have been identified as those areas that are subject to regular inundation, or are located immediately adjacent to surface water.

Lands that are subject to regular inundation (such as the Red River Valley) require special management because of the prolonged contact between water and the soil surface, and in particular, exposed manure. Therefore, practices that reduce the exposure of applied manure at the soil surface prior to inundation should reduce the risk of phosphorus transfer to floodwaters and, ultimately, to downstream drains and surface water bodies. One such practice is the elimination of winter application of manure. However, an immediate prohibition on winter spreading

for all agricultural operations within SMAs will have a severe financial impact on many smaller operations. Significant financial assistance and phasing-in of this prohibition will be required in order for these operations to comply.

Lands immediately adjacent to surface water or watercourses are at an elevated risk of contributing phosphorus simply due to their physical proximity. A number of management practices are suggested for reducing transfer of manure and manure phosphorus to surface waters. These include the establishment and/or maintenance of vegetated buffer strips and setback restrictions on manure application to adjacent land. The widths of the recommended buffers, and the management practices within, will vary depending upon the nature of the adjacent water body or watercourse.

Recommendation 2.0: Proposed livestock manure management practices for Special Management Areas.

2.1: In the Red River Valley, and in the designated floodplains of other rivers:

- Winter application of livestock manure should be prohibited, beginning immediately.
- Manure applied on tilled soils during the fall season should be injected into the soil, or in the case of surface application, should be incorporated into the soil within 48 hours. Incorporation or injection of manure is not required on perennial forage or no till systems.

2.2: Adjacent to lakes:

- A 15 metre permanently vegetated buffer strip should be maintained, within which manure application should not be allowed.
- For manure injection systems, or low level application systems with timely incorporation, manure application may begin at the outer edge of the proposed 15 metre wide buffer strip.
- For high level manure broadcast systems, or low level application systems with no incorporation, an additional 15 metre setback from the outer edge of the 15 metre wide buffer strip should be established within which manure application should not be allowed.

2.3 Along rivers, creeks and large un-bermed drains (3rd order or higher):

- A 3 metre permanently vegetated buffer strip should be maintained, within which manure application should not be allowed.
- For manure injection systems, or low level application systems with timely incorporation, manure application may begin at the outer edge of the proposed 3 metre buffer strip.
- For high level manure broadcast systems, or low level application systems with no incorporation, an additional 7 metre setback from the proposed 3 metre wide buffer strip should be established within which manure application should not be allowed.

2.4 Along smaller watercourses such as roadside ditches that are designated drains, and other lower order drains (1st and 2nd order):

- A 1 metre permanently vegetated buffer strip should be maintained, within which manure application should not be allowed.
- However, establishing and maintaining narrow permanently vegetated buffers strips may pose challenges for some producers. An acceptable alternate approach would be a 5 metre setback for manure application.

The preceding recommendations are only a first step towards improved environmental sustainability and are focused primarily on reducing excessive phosphorus loading onto agricultural land and adjacent water bodies from manure. They are based on the best available scientific information and judgment, but little scientific data related to this issue exists for Manitoba. The Committee recognizes there is a need for further site-specific research in this regard.

Recommendation 3.0: Research and review needs.

3.1 The Minister of Conservation should review the effectiveness of the new phosphorus-based regulation no later than five years after its coming into force.

3.2 Manitoba Conservation should work with other organizations to develop science-based, environmentally and economically sound beneficial management practices for reducing phosphorus losses to surface waters under Manitoba's soil, landscape, and climatic conditions.

Introduction

The primary concern surrounding phosphorus in Manitoba is the eutrophication of waterways and water bodies, and in particular, Lake Winnipeg. A recent report completed by Manitoba Conservation[1] showed that concentrations of phosphorus in many Manitoba rivers and streams are increasing. Increased phosphorus loads in rivers subsequently increases the loads that lakes receive and retain. There are many sources of phosphorus including urban, industrial, agricultural, and natural[2]. However, this report will focus on the land application of manure, and its potential impact on phosphorus in Manitoba soils and in surface waters.

The primary concern surrounding phosphorus in Manitoba is the eutrophication of waterways and waterbodies, and in particular, Lake Winnipeg.

Although phosphorus surpluses in the soil can occur on any type of agricultural operation, they are most often associated with livestock production. Currently in Manitoba, manure application to land is regulated on the basis of the nitrogen requirements of the crop, and does not consider the phosphorus needs of, or removal by, crops. Because of the imbalance of the concentrations of nitrogen (N) and phosphorus (P) in manure, this approach can result in over-application of phosphorus and a build-up of phosphorus in the soil.

Manitoba's livestock industry has expanded considerably over recent years and may continue to grow. The increase in livestock production has generated concern about environmental impact and sustainability of the industry. Public consultations carried out in the summer of 2000 by the Livestock Stewardship Panel resulted in a report[3] where some 40 recommendations were listed for consideration by government. One of these recommendations suggested that government should *"...move toward regulating manure application (to agricultural land) according to phosphorus"*.

Amendments to the *Livestock Manure and Mortalities Management Regulation* in 2004 included the requirement for the Minister of Conservation to review, by no later than March 31, 2006, *"the effectiveness of regulating manure application to land on the basis of nitrate nitrogen in the soil after reviewing any recommendations of the Phosphorus Expert Committee"*.

[1] Jones, Geoff and Nicole Armstrong, December 2001. Long-term trends in total nitrogen and total phosphorus concentrations in Manitoba streams, Manitoba Conservation Report No. 2001-07.

[2] Bourne, Alexandra, Geoff Jones and Nicole Armstrong, November 2002. A preliminary estimator of total nitrogen and total phosphorus loading to streams in Manitoba, Canada. Manitoba Conservation Report No. 2002-04.

[3] Tyrchniewicz, Ed, Nick Carter and John Whitaker, December 2000. Finding Common Ground – Sustainable Livestock Development in Manitoba, Report prepared for the Government of Manitoba by the Livestock Stewardship Panel.

Manitoba Phosphorus Expert Committee

In September 2002, the Minister of Conservation established the Manitoba Phosphorus Expert Committee (MPEC, or the Committee) to examine the issues surrounding phosphorus and livestock manure. Individuals chosen to serve on the Committee (Table 1) were selected based on their expertise and specialized knowledge. Examples of this knowledge and expertise brought to the Committee include phosphorus transport, phosphorus impacts upon surface water quality, phosphorus uptake and use by crops, phosphorus in manure, and environmental regulation.

Table 1: Manitoba Phosphorus Expert Commitee

Alfred Beck, Chair	Manager, Environmental Livestock Program	Manitoba Conservation
Dr. Sylvio Tessier, (Past Chair)	Bio-systems Engineer, Environmental Livestock Program	Manitoba Conservation
Dr. Cynthia Grant	Senior Research Scientist, Soil Fertility Management	Agriculture and Agri-Food Canada
Dr. Jane Elliott	Research Scientist	Environment Canada, Aquatic Systems Impact Research Centre, NWRI
Weldon Newton	Producer; Past-President of KAP	Keystone Agricultural Producers (KAP)
John Heard	Soil Fertility Specialist	Manitoba Agriculture, Food and Rural Initiatives
Petra Loro	Livestock Environmental Specialist, Animal Industry Branch	Manitoba Agriculture, Food and Rural Initiatives
Dr. Ian Seddon	Swine Specialist, Animal Industry Branch	Manitoba Agriculture, Food and Rural Initiatives
Mitchell Timmerman	Nutrient Management Specialist	Manitoba Agriculture, Food and Rural Initiatives
Mike Kagan, (Past member)	Soils Specialist, Environmental Livestock Program	Manitoba Conservation
Dave Green	Surface Water Quality Specialist	Manitoba Water Stewardship
Dr. Adrian Johnson	Western Canada Director	Potash and Phosphate Institute of Canada
Dr. Don Flaten	Associate Professor, Soil Science	University of Manitoba
Dr. Ken Snelgrove, (Past member)	Assistant Professor, Civil Engineering	University of Manitoba

** Committee Chair listed first, then members listed alphabetically by agency.*

The mandate given to MPEC was:

1. to summarize the state of the art in phosphorus cycling, transport processes and their relevance to Manitoba's climate, topography, and hydrology;
2. to review current phosphorus based environmental regulations or other management approaches implemented in other jurisdictions; and
3. to propose alternate strategies, regulatory or otherwise, that may be more effective in Manitoba for managing manure-phosphorus in a way that does not unduly limit crop and livestock production while increasing safeguards against overloading watercourses with crop nutrients.

The Committee recognized that there are many uncertainties about the amount of phosphorus in Manitoba's agricultural soils and about transport pathways for phosphorus export to watercourses from farmland associated with livestock production. Moving towards regulation of manure application on the basis of phosphorus is complex and needs to be carefully considered.

To meet its mandate, the MPEC sought input from several sources. A number of specialists were invited to present information and to share their knowledge with the Committee. (See Appendix A.) In addition, the MPEC reviewed programs, regulations, and policies from other jurisdictions such as the United Kingdom, North Carolina, Ontario, Alberta, Minnesota, and Quebec.

The Committee was also fortunate to have access to the information contained in two reports prepared by scientists from the University of Manitoba and Agriculture and Agri-Food Canada for the Manitoba Livestock Manure Management Initiative (MLMMI). The first report[4] was a review of literature regarding the behavior of phosphorus in agricultural production systems, and the adaptation of existing knowledge to the Manitoba situation. Knowledge gaps were identified and actions to address these gaps were suggested.

The second report[5] investigated the feasibility and effectiveness of several options for regulating phosphorus management in Manitoba, and conducted four case studies to evaluate the impact of various regulatory options for phosphorus management on Manitoba hog farms. These reports may be viewed on the MLMMI website at www.manure.mb.ca.

In April 2003, the MPEC sponsored the Agricultural Phosphorus Update 2003 Symposium. International experts on phosphorus processes were invited to share their views and knowledge on environmental phosphorus, and on the effectiveness of beneficial management practices and regulatory approaches.

A better understanding of the importance of snowmelt and flooding events in phosphorus loss is required.

The discussion identified many research and development needs related to phosphorus issues in Manitoba. Among these was the influence of soil management, climate, and landscape on phosphorus losses. It was emphasized that a better understanding of the importance of snowmelt and flooding events in phosphorus loss is also required. Discussions also took place concerning mitigation approaches and beneficial management practices for phosphorus management.

In October 2004, Manitoba Agriculture, Food and Rural Initiatives (MAFRI) hosted the conference "Living with Livestock – Environment and Change" in Winnipeg. Scientists from around the world made presentations to the conference. Proceedings of the conference may be viewed on MAFRI's website at www.gov.mb.ca/agriculture/livestock/index.html. The MPEC was able to take advantage of the opportunity to meet with several of these scientists to discuss specific Manitoba issues, and to learn more about approaches being taken elsewhere.

[4] Flaten, Don, Ken Snelgrove, Ian Halket, Kathy Buckley, Grant Penn, Wole Akinremi, Brian Weibe, and Ed Tyrchniewicz. May 2003. Acceptable Phosphorus Concentrations in Soils and Impact on the Risk of Phosphorus Transfer from Manure Amended Soils to Surface Waters. Phase 1: A Review of Literature for the Manitoba Livestock Manure Management Initiative.

[5] Salvano, Esther, Ed Tyrchniewicz, and Don Flaten. March 2004. Acceptable Phosphorus Concentrations in Soils and Impact on the Risk of Phosphorus Transfer from Manure Amended Soils to Surface Waters. Phase 2: Feasibility and Effectiveness of Several Options for Regulating Manure Phosphorus Management in Manitoba.

The Facts about Phosphorus

What is phosphorus?

Phosphorus is an element that occurs naturally in the environment and is present to varying degrees in all soils.

Phosphorus is essential to life on this planet. It is required by all living organisms for the basic processes of life. In humans, phosphorus in one form or another is the second most abundant mineral in the body, next to calcium. In all animals, including humans, it is required for bone growth and tooth development. It is present in every living cell in the body and is necessary for many physiological and biochemical processes within the body.

Phosphorus is important for crop nutrition. It is used to form proteins, co-enzymes, nucleic acids, cell membranes, and is involved in energy transfer. It has been shown to increase root development, especially in cool, wet springs. This additional root development increases the plant's ability to uptake nutrients, which in turn promotes early crop development, seed development, disease resistance, and early maturity. Sufficient plant-available phosphorus along with a balance of other nutrients can increase yields.

Phosphorus is essential to life on this planet.

All living organisms contain phosphorus, and at the end of their life cycles, that phosphorus is returned to nature from decomposing material.

The phosphorus issue in Manitoba

Lakes and streams of southern Manitoba are naturally enriched with phosphorus. However, human activities also contribute additional phosphorus to the environment. Phosphorus is present in many detergents, and in fertilizers used for domestic and commercial purposes. Sewage from industry, towns, cities, and individual septic systems contribute phosphorus to the surface waters of the province. Agricultural sources of phosphorus to the environment include livestock manure, commercial fertilizers, and crop residues.

The increased loading of phosphorus to Manitoba's surface waters has compromised water quality and has raised concerns over the potential for eutrophication[6] of many of the province's lakes. Algae blooms are the main indicator of the process of eutrophication.

Increased loading of phosphorus to Manitoba s surface waters has compromised water quality.

In recent years, the increased occurrence and intensity of algae blooms on Lake Winnipeg have raised concerns over water quality in the lake. As plants, algae thrive on nutrients entering the lake, but most particularly, phosphorus. While algae are present in all aquatic systems, an over-abundance leads to water quality issues. As the algae die and sink into the lake, oxygen is consumed from the surrounding water. This presents a threat to aquatic life such as fish.

Modern agriculture requires that reasonable amounts of crop nutrients including phosphorus be added to soils for fertilization of crops. Phosphorus is relatively immobile in the soil when compared to nitrogen. However, even small amounts of phosphorus in surface water can have a significant effect on water quality. What may seem to be an insignificant amount of phosphorus from a soil fertility perspective may be considered a huge amount from a water quality perspective.

[6] Eutrophication is the nutrient enrichment of a water body which leads to increased algae growth.

The Process of Phosphorus Loss

Phosphorus from agricultural activities may originate from point sources and non-point sources. Examples of point sources include individual manure storage facilities and intensive livestock operations such as feedlots. However, the Manitoba Phosphorus Expert Committee's focus is primarily on non-point sources of phosphorus from agriculture. These include wider geographic areas and involve the loss of phosphorus from the landscape and soils in general, rather than single, well-defined sources.

Phosphorus loading

Phosphorus loading occurs when the amount of phosphorus imported into an area exceeds the amount that is exported.

Phosphorus loading is the accumulation of phosphorus in a given area that results when the amount of phosphorus imported into the area exceeds the amount that is exported. Some examples of imported phosphorus include livestock feed and feed supplements brought into the area, and commercial phosphorus fertilizer imported and applied to the land.

All plants and animals consume and retain a certain amount of phosphorus, whether from the soil in the case of plants, or for animals, from the food they ingest. In this manner, phosphorus may be exported from an area as plant products (vegetables, grain, hay, straw) or animal products (on-the-hoof, meat, eggs, milk and similar items). Phosphorus may also be exported, particularly at the farm scale, as manure. However, this can be a very expensive option if manure must be shipped out of the region, particularly for liquid manures.

Phosphorus may be exported from an area as plant products (vegetables, grain, hay, straw) or animal products.

Phosphorus loading can occur at various scales including regional, on-farm, or in a specific field and is often associated with livestock production systems. When more phosphorus is imported into a given region than is exported, loading occurs at the regional scale. Similar situations can occur at the farm-scale. At the field scale, if more phosphorus is applied to land than can be removed in the harvested portion of the crop, phosphorus will accumulate in the soil.

Most of the total phosphorus consumed by an animal is expelled as feces and urine. The feces and urine may be recycled on the farm as crop fertilizer. But when more manure phosphorus is added to the soil than the crop can remove, loading of the soil occurs. This is often the case when manure is used as a nitrogen fertilizer. This may also occur with commercial phosphorus fertilizer.

Livestock in outdoor grazing systems and wintering sites also contribute nutrients to the landscape. Manure phosphorus may accumulate in the soil when the amount added to the soil exceeds the amount being exported through livestock products, or from hay and forages harvested from the site.

Phosphorus mobilization

For phosphorus from agricultural sources to impact surface water quality, it must move from the landscape and soil to water. The processes involved are mobilization and delivery.

Mobilization of phosphorus occurs when conditions are created that start the movement of phosphorus from the land to water. The phosphorus may be mobilized in particulate form, in a dissolved form, or directly as commercial fertilizer or manure through a process called incidental transfer.

Most phosphorus in the soil is in a particulate form, that is, it is attached to soil particles. This phosphorus is mobilized when soil is eroded by water, and to a lesser degree, wind erosion.

Phosphorus may also be mobilized in its soluble, or dissolved, form. Once phosphorus becomes soluble, it moves with water and is very difficult to control. As the amount of phosphorus in the soil increases, dissolved phosphorus usually increases also. The most effective way to reduce the risk of phosphorus loss as soluble phosphorus is to control the build-up of phosphorus in the soil.

Once phosphorus becomes soluble, it moves with water and is very difficult to control.

Incidental transfer of phosphorus is the direct transport of manure or fertilizer into a watercourse or a water flow path leading to a water body. For example, incidental transfer can occur when manure is surface-applied and then washed off by rainfall or snowmelt runoff. Winter or late fall surface application of manure increases the risk of incidental transfer of phosphorus from manure to water during spring runoff.

Direct deposition of manure is the direct application of nutrients into a ditch or water course. This may happen when manure or fertilizer is inadvertently spread into adjacent drainage ditches or watercourses, or by tillage equipment operating too near, or in, ditches. Phosphorus in manure can be deposited directly into water by livestock with direct access to the watercourse.

Manure may be inadvertently spread into adjacent ditches or water courses.

Phosphorus delivery

Delivery is entry of phosphorus into a surface water pathway. Although phosphorus may have moved within a field or out of a field, it can still be captured before it enters surface water. Capturing the phosphorus before it enters surface water reduces delivery and, ultimately, impact.

Phosphorus impact

The impact of excess phosphorus on surface waters is the deterioration of surface water quality. This manifests itself in algae blooms frequently seen on water bodies in Manitoba ranging from potholes and small lakes to large water bodies such as Lake Winnipeg.

The impact of excess phosphorus manifests itself in algae blooms.

Beneficial Management Practices

Beneficial Management Practices (BMPs) are activities that reduce the negative impacts of agricultural activities on the environment. It is the Committee's opinion that the adoption of BMPs that mitigate the risk of phosphorus loss from agricultural land is key to protecting surface water quality in Manitoba. In consideration of this, the Committee has prepared a list of BMPs which will, or have the potential to, minimize the impacts of phosphorus, specifically phosphorus in livestock manure, on the environment. The environmental effectiveness of many of these BMPs has not been validated under Manitoba conditions – a critical step in the move toward BMP adoption at the farm-level. In addition, the economic implications of adoption are not discussed. For a summary of BMPs considered by the Committee, see Appendix B.

Key to phosphorus management is to address phosphorus loading to the landscape.

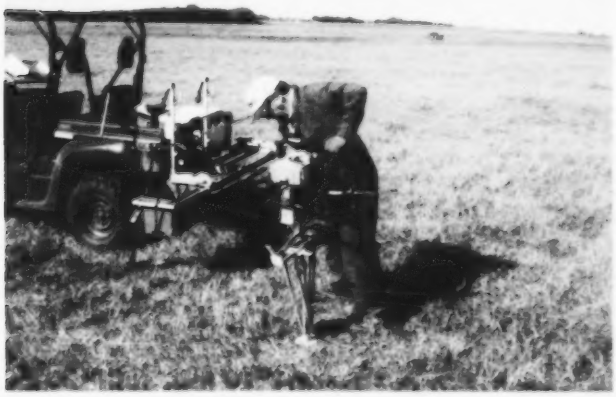
Key to phosphorus management is to address phosphorus loading to the landscape. Several activities and practices can be employed to reduce phosphorus loading, whether to a region, on an individual farm, or in a specific field. In general, these involve minimizing phosphorus imports into an area while maximizing exports.

Reducing phosphorus loading to an area can begin with minimizing the amount of phosphorus imported through livestock feed and feed additives or commercial fertilizers. Replacing commercial fertilizer phosphorus with manure phosphorus already available on the farm for crop production reduces phosphorus imports to an area.

Throughout, proper soil testing is crucial to effective phosphorus management. Soil testing will determine the amount of available soil phosphorus, which in turn can be used to establish phosphorus application rates, whether through manure or commercial fertilizers. Phosphorus efficiency can be maximized through proper timing and placement. Application equipment should be selected and calibrated to optimally distribute nutrients and meet target application rates.

When using manure as a nitrogen-based fertilizer, fields for application should be rotated where possible to minimize the potential for phosphorus loading. Since nitrogen in manure is volatile and easily lost to the atmosphere, efforts should be made to conserve the nitrogen in manure during storage, handling, and land application. The more nitrogen that is conserved, the lower the manure application rate, and therefore the lower the phosphorus application.

Soil testing will determine the amount of available soil phosphorus.



Land should be prioritized for manure additions based on soil test phosphorus levels and manure phosphorus concentrations. Solid-liquid separation of manure allows the phosphorus-rich solids to be managed separately from the more dilute liquids. More concentrated manure should be applied to fields with lower soil test phosphorus values while dilute manures would be applied to fields with higher soil test values. Fields with very high soil phosphorus levels should be rotated, where possible, in order to limit further build-up in phosphorus or to draw down phosphorus levels though phosphorus export in the harvested portion of the crop.

Phosphorus exports can be optimized through management practices that increase the amount of phosphorus in the exported material. For example, since healthy animals are more efficient at using nutrients such as phosphorus, BMPs that improve animal health and efficiency will optimize phosphorus use and

subsequent export. BMPs that improve overall crop production will increase the export of phosphorus in harvested products. Crops that maximize phosphorus removal such as high-yielding canola and alfalfa should be included in the crop rotation.

Livestock in outdoor grazing systems and wintering sites also contribute nutrients to the landscape. Cattle distribution and density should be managed to avoid manure accumulation in any one location, particularly hydrologically active areas (where water flows/accumulates). Long-term application rates of manure or commercial fertilizer that are higher than the net rate of removal by grazing livestock should be avoided on grazing land. Periodically harvesting forage as hay from a pasture will increase the export of phosphorus. Manure from over-wintering sites can be collected and applied as a fertilizer to cropland.

There are a number of BMPs that show promise for reducing phosphorus mobilization.

There are a number of BMPs that show promise for reducing phosphorus mobilization. Employing practices that control soil erosion will control the movement of particulate phosphorus. Application practices that reduce the exposure of manure to rainfall and spring snowmelt such as injection or timely incorporation by tillage will help to reduce the incidental transfer of phosphorus to water. Winter or late fall surface application of manure increases the risk of incidental transfer of phosphorus from manure to water during spring runoff. The elimination of the practice, especially in more sensitive areas, would reduce that risk.

Diverting clean run-on water from entering open confined livestock or manure storage areas minimizes the quantity of contaminated water to manage as runoff exiting the open confined area. Livestock access to surface water should be controlled to reduce the direct deposition of manure phosphorus into water by the cattle.

Controlling the delivery of phosphorus into surface waters may be managed to some degree with BMPs that can filter or contain the phosphorus before it enters surface water. These may include the establishment of vegetated buffer strips along watercourses. Natural or constructed wetlands can be employed to collect and treat runoff from agricultural cropland and intensive livestock areas.

Application practices that reduce the exposure of manure to rainfall and spring snowmelt will help to reduce the incidental transfer of phosphorus to water.

Issues and Recommendations

The focus for regulating phosphorus in Manitoba should be to minimize the risk of phosphorus loss to surface water by reducing excessive phosphorus loading onto land and minimizing the mobilization and delivery of phosphorus to water. General discussions of processes involved in phosphorus loss, and the need for BMPs to address this loss were presented in the previous sections. A summary of BMPs that may have benefit in managing phosphorus on the Manitoba landscape – as related to livestock manure in particular – is presented in Appendix B.

Soil Test Phosphorus Thresholds

Since phosphorus is universally present in soils whether in farmland, forest, or other natural settings, zero-discharge of this element into surface watercourses will never be achieved. However, there is concern with the build-up of phosphorus in agricultural soils and the increased risk of phosphorus moving to surface water if soil test phosphorus concentrations have reached unacceptable levels.

When manure is managed as a nitrogen fertilizer, it often supplies more phosphorus to the soil than the crops can use.

Very high soil phosphorus levels are most often associated with livestock production, and the application of livestock manure to cropland. Manure is most valuable as a fertilizer when it is applied based on the nitrogen requirements of the crop. But when managed as a nitrogen fertilizer, manure often supplies more phosphorus to the soil than the crops can use. If more phosphorus is applied to land over time than can be removed in the harvested portion of the crop, then the remaining phosphorus will accumulate in the soil. The enrichment may eventually pose an unacceptable risk to the environment.

Soils do not have an infinite capacity to retain phosphorus. Literature reviewed by the Committee indicates that as soil test phosphorus increases to very high levels, losses of soluble phosphorus and particulate phosphorus, due to runoff and erosion, respectively, can also increase. It is generally agreed by members of the Manitoba Phosphorus Expert Committee that soil test phosphorus levels should not be allowed to increase to extremely high levels.

Soil testing for phosphorus is a useful tool for nutrient management and regulation, but it is not precise. This is because soil test phosphorus concentrations vary tremendously with time, space, and environmental conditions, even when no additional phosphorus is applied. Therefore, regulating solely on the basis of an absolute soil test phosphorus limit (i.e. a single value) would be very challenging. From the perspective of "legal proof", there could be a significant number of mistakenly identified situations of apparently "excess phosphorus". For this reason, it may be more effective to use soil test ranges to trigger a management response.

The long-term sustainability of livestock production relies on the availability of adequate, suitable land for manure application. Many soils in Manitoba benefit agronomically from some build-up in soil test phosphorus without posing a risk to environmental quality. Surpluses of phosphorus in the field should be managed by balancing inputs with crop requirements and removals over the long term, *while allowing for modest accumulations of soil test phosphorus where it is agronomically and economically desirable and environmentally acceptable over the short term*. There must be a balance between the application of management practices that mitigate the risks of environmental impacts from phosphorus and economically viable food production.

Long-term planning for new or expanding livestock operations should ensure the availability of a cropped land base within the region that will allow application of manure phosphorus at no more than can be removed by a crop in one year. This would provide the greatest flexibility and would ensure that livestock producers have enough land to apply manure into the foreseeable future. Over time, access to additional fields for manure application may be required where repeated applications of manure have resulted in excessive soil test phosphorus build-up.

As a cautionary note, some livestock producers may find it difficult to find enough appropriate land nearby for applying their manure on the basis of phosphorus removal by the crop. Some areas with intensive livestock production may already have soil phosphorus levels that are approaching or already exceed unacceptable levels, and sufficient additional spread lands may not be available within economically viable distances for transport of manure. Financial support for options such as relocation or installation of treatment systems may need to be considered in order for these operations to comply. Alternatively, these operations may require additional time to develop new technologies or strategies in order to adapt to new phosphorus management approaches.

Discussion

Because soil testing is not a precise science, the Manitoba Phosphorus Expert Committee decided that the most promising approach to regulating the land application of phosphorus is to use soil test phosphorus threshold ranges to require a change in management (Table 2 on the following page). The soil test phosphorus threshold approach developed by the Committee takes into consideration the regulatory approaches used in other jurisdictions, particularly Ontario and Minnesota. It also takes into consideration, as much as possible at this time, our understanding of phosphorus behaviour in Manitoba.

Four ranges of soil test phosphorus thresholds are proposed and imply an increasing degree of restriction for land application of livestock manure.

For example, one of the most important mechanisms by which phosphorus enters surface waters in Manitoba is thought to be as soluble phosphorus via snowmelt and spring runoff. Unfortunately, however, this mode of phosphorus loss under Manitoba soil, landscape, and climatic conditions is not well understood.

The environmental risk associated with elevated soil phosphorus concentrations arising from livestock manure applications should be managed through incrementally restrictive requirements for use of phosphorus at different thresholds of soil test phosphorus. In summary, four ranges of soil test phosphorus thresholds are proposed and imply an increasing degree of restriction for land application of livestock manure based upon the soil's phosphorus content.

Soil test phosphorus is the concentration of extractable phosphorus[7] in soil samples taken from the zero to six-inch (0-15 cm) soil layer, using the sodium bicarbonate extractant procedure (Olsen procedure)[8] or an equivalent method recognized by Manitoba Conservation. The soil depth for phosphorus testing is different from nitrate-nitrogen which should be sampled from the soil surface down to 24 inches (0-60 cm).

[7] Extractable phosphorus refers to the amount of phosphorus that can be extracted in solution from a soil sample in a soil test procedure, and does not represent all of the phosphorus in the soil.

[8] The Olsen procedure is an industry-accepted method of determining soil test phosphorus, particularly in soils of neutral to high pH levels such as those common in Manitoba.

The MPEC proposes to use a soil test phosphorus concentration of 60 parts per million (ppm)[9] as the level at which measures should be instituted to slow down the rate of phosphorus accumulation in soil. Where the soil test phosphorus concentration is less than 60 ppm, no phosphorus-based management restrictions are proposed. It is recommended that manure be applied based on the nitrogen requirements of the crop, which is the most economical method of applying manure.

Agronomic response to phosphorus above initial starter levels is not expected when soil test phosphorus exceeds 60 ppm.[10] When soil test phosphorus concentrations exceed 60 ppm, management of phosphorus application to the land will be required to control the phosphorus accumulation rate.

The Committee is recommending that, for Manitoba, when soil test phosphorus concentrations are between 60 ppm and 119 ppm, action should be taken to slow down the accumulation of phosphorus in the soil. Manure may be applied at a rate no greater than two times crop removal of phosphorus to control soil test phosphorus build-up.

Above 180 ppm soil test phosphorus, efforts must be made to draw down the amount of phosphorus in the soil.

For soil test phosphorus concentrations between 120 and 179 ppm, the manure phosphorus additions must be managed to avoid any further increases. In order to balance inputs with outputs, manure application at a rate of no more than one times the crop removal rate is recommended to prevent further increases in soil test phosphorus concentrations over time.

Above 180 ppm soil test phosphorus, additional manure applications would be prohibited unless the operation receives written approval from an employee of Manitoba Conservation who has been appointed as the Director. At this point, efforts must be made to draw down the amount of phosphorus in the soil through crop removal.[11]

Table 2: A summary of proposed soil phosporus (P) thresholds for regulating livestock manure application on cropland in Manitoba.

Soil Test P Threshold (Olsen P or equivalent)	Intent of Threshold	Manure P Application
Less than 60 ppm P	No restriction on P application	Apply on the basis of crop nitrate nitrogen (N) requirements. Soil N concentrations are subject to section 12 of LMMMReg
Between 60 and 119 ppm P	Control soil P accumulation rate	Apply P up to 2 times the crop removal rate of P_2O_5
Between 120 and 179 ppm P	Prevent further increases in soil P concentrations	Apply P up to 1 times the crop removal rate of P_2O_5
180 ppm or greater P	Depletion at a rate controlled by crop removal	No manure application without written consent of the Director

[9] All soil test phosphorus concentrations referred to in this discussion are as determined by the Olsen procedure or equivalent.

[10] http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag6741

[11] This is more restrictive than both Ontario and Minnesota but may be necessary to provide that, over the long-term, soil phosphorus levels do not reach the extremely high concentrations experienced in some locations in other parts of the world.

In the case of livestock manure, phosphorus applications are planned on the basis of total phosphorus concentrations in the manure, expressed in commercial phosphorus fertilizer (P_2O_5) equivalent. If commercial fertilizer applications are planned, the amount of phosphorus that is applied to a field as manure should be deducted from the crop removal rate for phosphorus. The crop removal rate is expressed as P_2O_5. The crop removal rate is the amount of phosphorus removed, or exported, from a site as seed and crop residue. It does not include the amount remaining on the field after harvest as residue such as crop stubble.

The crop removal rate is the amount of phosphorus removed from a site as seed and crop residue.

Crop removal rates for various crops are available in the document "Nutrients Removed in Harvested Portion of Crop" (Potash and Phosphate Institute/ Potash and Phosphate Institute of Canada. Last updated in February 2001)[12] or the "Soil Fertility Guide" (Manitoba Agriculture, Food and Rural Initiatives, 2001)[13], and are expressed in P_2O_5 equivalent.

In addition to the soil test phosphorus thresholds, the current restrictions for nitrogen loading also apply to all lands that receive manure[14].

Based on current limitations of manure application equipment and economic application rates, the MPEC proposes to also allow single, multi-year phosphorus applications of up to five years of crop removal. A multi-year removal rate of P_2O_5 (up to 5 years) could be applied in one year followed by no manure for the following years. This will encourage rotation of fields for manure application and the long-term sustainability of the operation.

These ranges of soil test phosphorus thresholds recognize agronomic needs for phosphorus as a major crop nutrient, the increasing environmental risk associated with soil test phosphorus thresholds beyond those judged optimal for crop production, and the complicated management issues associated with soil and manure phosphorus. The intent of the thresholds is to trigger an appropriate management response by the producer. In other words, enforcement action would be based on management response rather than soil test phosphorus concentrations *per se*.

The intent of the thresholds is to trigger an appropriate management response by the producer.

Soil Test Phosphorus Thresholds Recommendations

The Manitoba Phosphorus Expert Committee presents the following recommendations for consideration.

Recommendation 1.0: Soil test phosphorus thresholds

1.1 For soil test phosphorus concentrations of less than 60 parts per million (ppm)[15], no restriction on phosphorus application is required. Livestock manure may be applied based on crop nitrogen requirements.

1.2 For soil test phosphorus concentrations of 60 to 119 ppm, efforts must be made to control phosphorus accumulation in the soil profile. Livestock manure may be applied based on a rate up to two times the rate of crop removal of P_2O_5.

1.3 For soil test phosphorus concentrations of 120 to 179 ppm, further increases in phosphorus in the soil profile must be controlled. Livestock manure may only be applied at a rate up to one times the crop removal rate of P_2O_5.

1.4 For soil test phosphorus concentrations of 180 ppm or more, efforts must be made to reduce the amount of phosphorus in the soil profile. Livestock manure may not be applied without the written consent of the Director[16].

[12] http://ppi-ppic.org

[13] Available at no charge on-line at www.gov.mb.ca/agriculture/soilwater/index.html#fertility, or from various Manitoba Agriculture, Food and Rural Initiatives offices.

[14] Section 12 of the *Livestock Manure and Mortalities Management Regulation*.

[15] As determined by the Olsen procedure or equivalent.

[16] The Director refers to an employee of Manitoba Conservation appointed as Director.

Special Management Areas

There are geographic areas within Manitoba that require special consideration when implementing management strategies to mitigate the risk of phosphorus loss. These Special Management Areas (SMAs) have certain properties of location, soil, climate, and topography that make them likely sources of phosphorus loss to surface water.

SMAs in Manitoba have been identified as those areas that are subject to regular inundation, or immediately adjacent to surface water – lakes, or rivers, creeks and large un-bermed drains, or other watercourses and roadside ditches.

Special Management Areas have certain properties that make them likely sources of phosphorus loss to surface water.

Because of their characteristics, SMAs provide only limited opportunity for the natural reduction of phosphorus movement before it is transported to surface water. In light of this elevated risk, adoption of certain recommended practices to influence the processes involved in phosphorus transfer to surface water is more critical than in the rest of the landscape. The intent of requiring certain practices for SMAs is to enhance the separation between phosphorus, both dissolved and particulate, and water that ultimately connects to a surface water body. This separation can be temporal (*e.g.*, timing of application relative to spring snowmelt) or spatial (*e.g.*, proximity to surface water).

Discussion

The following discussion and the development of the subsequent recommendations take into consideration the scientific literature and regulatory approaches from neighbouring jurisdictions, particularly Ontario and Minnesota. They also take into consideration, as much as possible at this time, our understanding of local hydrology, agricultural practices, the landscape, and phosphorus transport in Manitoba.

Regularly inundated lands (Red River Valley and other floodplains)

Lands that are subject to regular inundation, whether by overflow from a water body or by precipitation or snowmelt exceeding the land's capability to drain, require special management because of the prolonged contact between water and the soil surface, and in particular, exposed manure. There is an increased potential for the transfer of phosphorus to overlying floodwaters.

There is an increased potential for the transfer of phosphorus to overlying floodwaters on lands that are subject to regular inundation.

The Red River Valley is designated as an SMA. The area included is that portion of the Valley that is regularly inundated during spring snowmelt, including that portion of the valley outside of the Red River's 1 in 100 year floodplain that is also subject to annual flooding from overland runoff. (Figure 1) Other natural floodplains throughout the province such as low lying areas of the Souris and Assiniboine river valleys, for example, are also considered to be SMAs.

Proximity to a permanent surface water body is not the criterion for designating regularly inundated lands as SMAs. Rather, it is the high degree of risk that exists for the transfer of manure phosphorus into the water body from adjacent land, whether through drainage, natural or artificial, overland runoff, or inundation. Under these conditions, manure could be directly transferred to surface water, especially if the manure has been deposited on frozen ground or on top of the snow. Therefore, practices that reduce the exposure of applied manure at the soil surface prior to inundation should reduce the risk of phosphorus transfer to floodwaters and, ultimately, to downstream drains and surface water bodies. One such practice is the elimination of winter application of manure.

Figure 1: Red River Valley Special Management Area

Injection or incorporation of manure is most critical in the fall on regularly inundated lands.

Large livestock operations are already prohibited from land-applying manure during the winter. The prohibition should be extended to include all sizes of operations that spread manure on regularly inundated lands. This should significantly reduce the direct transfer of manure to surface waters from frozen and snow-covered soils. However, an immediate prohibition on winter spreading will have severe financial impact on many existing small poultry and livestock operations that currently lack the capacity to store manure over winter. Significant financial assistance and phasing-in of this prohibition will be required in order for these operations to comply.

Another practice that should reduce the risk of phosphorus transfer from manure to floodwaters is subsurface placement of manure by injection or incorporation by tillage immediately following broadcast application. Injection or incorporation of manure is most critical in the fall on regularly inundated lands so that there is minimal or no exposure at the soil surface prior to spring snowmelt. However, special consideration should be given to no-till systems that receive manure where injection or incorporation is not feasible. In these situations, the risk posed by surface application of manure may be partially offset by reduced risk of erosion and runoff, compared to cultivated annual cropland.

Lands immediately adjacent to surface water or watercourses

Lands immediately adjacent to surface water or watercourses are at an elevated risk of contributing phosphorus simply due to their physical proximity. The following practices are suggested for reducing transfer of manure and manure phosphorus to surface waters. These include the establishment and/or maintenance of vegetated buffer strips and setback restrictions on manure application to adjacent land. No manure should be applied to the permanently vegetated buffer strips.

Vegetated buffer strip.

Maintaining narrow strips of perennial vegetation on the edges of tilled fields – buffer strips – reduces the risk of direct deposition of manure phosphorus into surface water and watercourses. Wider buffer strips can reduce nutrients and other contaminants by decreasing velocity of runoff that induces particulate deposition. Buffer strips can also increase infiltration which subsequently reduces runoff volume, lower phosphorus concentrations in buffer strip soils, and allow increased adsorption of nutrients. If wide enough, buffer strips can be more effective at reducing particulate phosphorus although some studies have also found reductions for soluble phosphorus[17, 18].

The buffer strip widths in the range of five to 30 metres being recommended are generally within the ranges of those shown in the literature to provide phosphorus reductions[19, 20, 21].

For the least significant watercourses such as roadside ditches that are designated drains, and other lower order drains (1st or 2nd order[22]), a buffer strip of one metre wide is recommended. These watercourses are usually intermittent and contain water only occasionally such as during spring runoff or heavy precipitation events where transport of nutrients would usually occur. The

[17] Schmitt, T. J., M. G. Dosskey, and K. D. Hoagland. 1999. Filter strip performance and processes for different vegetation widths, and contaminants. J. Environ. Qual., Vol 28: 1479 – 1489.

[18] Daniels, R. B. and J. W. Gilliam. 1993. Sediment and chemical load reduction by grass and riparian filters. Soil Sci. Soc. Am. J. 60: 246 – 251.
Also others.

[19] Abu-Zreig, M., R. P. Rudra, H. R. Whiteley, M. N. Lalonde, and N. K. Kaushik. 2003. Phosphorus removal in vegetated filter strips. J. Environ. Qual. 32: 613 – 619.

[20] Castelle, A. J., A. W. Johnson, and C. Conolly. 1994. Wetland and stream buffer size requirements - a review. J. Environ. Qual., Vol 23: 878 – 882.

[21] Johnson, A. W. and D. M. Ryba. 1992. A literature review of recommended buffer widths to maintain various functions of stream riparian areas. King County Surface Water Manage. Div., Seattle, WA.; and others.

[22] Drain order may be determined by reference to drainage maps which may be obtained from Manitoba Water Stewardship or by on-line reference to Agri-Maps on the Manitoba Agriculture, Food and Rural Initiatives website.

intent is to reduce the opportunity for direct phosphorus addition to surface water bodies through manure application or tillage. However, establishing and maintaining 1 metre permanently vegetated buffer strips may pose challenges for some producers. An acceptable alternate approach would be a 5 metre setback for manure application.

More significant water features such as rivers or creeks[23] require wider buffer strips than intermittent ditches or small watercourses because the presence of water is continual and they are more likely to transport significant amounts of nutrients. These water bodies also have a greater susceptibility to the effects of nutrient overloading. Wider buffer strips also provide enhanced filtering and nutrient adsorption of manure residues moving off-field during runoff events.

The widest buffers are being recommended for lakes because eutrophication occurs at lower phosphorus levels in lakes than in flowing water. Also, lakes allow settling of sediments and thereby retain more of the phosphorus loading received from the surrounding landscape and from watercourses draining into them.

Table 3: A Summary of proposed livestock manure management practices for Special Management Areas (SMAs)

SMA Type	Winter or Fall Application / Buffers	Manure Application Setbacks	
		Injection / low level application with incorporation	High level broadcast application / low level application with no incorporation
Red River Valley or flood plains of other designated rivers	Immediate prohibition on all winter application; Incorporation within 48 hours or injection of fall applied manure on tilled soils.		
Lakes	Permanently vegetated buffer strip of 15 m; no manure application	15 m setback	30 m setback
Rivers, creeks and large unbermed drains (3rd order or higher)	Permanently vegetated buffer strip of 3 m; no manure application	3 m setback	10 m setback
Smaller watercourses such as roadside ditches that are designated drains, and other lower order drains (1st and 2nd order).	Permanently vegetated buffer strip of 1 m; no manure application	1 m setback	1 m setback

[23] As identified on 1:50,000 scale National Topographic Series maps.

Manure application methods have also been considered in the recommendations. Manure may be injected into the soil, or surface applied. Surface-applied methods include low level systems such as "dribble" applications, or high level systems such as broadcast application from a traditional spreader. Subsurface injection is precise, reducing the risk of direct deposition and transport with runoff of manure into surface waters when compared to surface application without incorporation. Therefore, narrower setback widths are acceptable for manure injection systems.

Literature[24] indicates that vegetated buffer strips may not always be effective at reducing phosphorus loading. In fact, they may occasionally be a source of phosphorus to surface waters, and as such, require special management. Harvesting of the perennial vegetation in the buffer strip serves as a means to remove accumulated phosphorus in plant tissue. This vegetation may have potential as a source of livestock feed.

Recommendations for Phosphorus Management in SMAs

The Manitoba Phosphorus Expert Committee presents the following recommendations related to Special Management Areas.

Recommendation 2.0: Proposed livestock manure management practices for Special Management Areas.

2.1: In the Red River Valley, and in the designated floodplains of other rivers:

- Winter[25] application of livestock manure should be prohibited, beginning immediately.
- Manure applied on tilled soils during the fall season[26] should be injected into the soil, or in the case of surface application, should be incorporated into the soil within 48 hours. Incorporation or injection of manure is not required on perennial forage or no till systems.

2.2: Adjacent to lakes:

- A 15 metre permanently vegetated buffer strip should be maintained, within which manure application should not be allowed.
- For manure injection systems, or low level application systems with timely incorporation, manure application may begin at the outer edge of the proposed 15 metre wide buffer strip.
- For high level manure broadcast systems, or low level application systems with no incorporation, an additional 15 metre setback from the outer edge of the 15 metre wide buffer strip should be established within which manure application should not be allowed.

2.3 Along rivers, creeks and large un-bermed drains (3rd order or higher):

- A 3 metre permanently vegetated buffer strip should be maintained, within which manure application should not be allowed.
- For manure injection systems, or low level application systems with timely incorporation, manure application may begin at the outer edge of the proposed 3 metre buffer strip.
- For high level manure broadcast systems, or low level application systems with no incorporation, an additional 7 metre setback from the proposed 3 metre wide buffer strip should be established within which manure application should not be allowed.

2.4 Along smaller watercourses such as roadside ditches that are designated drains, and other lower order drains (1st and 2nd order):

- A 1 metre permanently vegetated buffer strip should be maintained, within which manure application should not be allowed.
- However, establishing and maintaining narrow permanently vegetated buffers strips may pose challenges for some producers. An acceptable alternate approach would be a 5 metre setback for manure application.

[24] Sheppard, S.C., M.I. Sheppard, J. Long, B. Sanipelli and J. Tait. 2005. Field validation of vegetated buffer strips to mitigate phosphorus runoff. ECOMatters Inc., Pinawa, Manitoba. Under review.

[25] Winter, as defined by the Livestock Manure and Mortalities Management Regulation, is from November 10 to April 10.

[26] Fall, as suggested by the MPEC, is from September 10 to November 10.

Research and Review to Develop a More Site-Specific Approach

Discussion

The preceding recommendations are only a first step towards improved environmental sustainability and are focused primarily on reducing excessive phosphorus loading onto agricultural land and adjacent water bodies from manure. They are based on the best available scientific information and judgment, but little scientific data related to this issue exists for Manitoba.

The previous recommendations consider only the land application of manure and do not address other potential sources of phosphorus contamination. In addition, these recommendations do not address phosphorus transport factors other than the direct, incidental contamination of water from surface-applied manure. For example, phosphorus losses from highly erosive soils and steeply sloping lands are not addressed. Further site-specific research is needed in this regard.

Recommendations Regarding Research and Review Needs

The Manitoba Phosphorus Expert Committee presents the following recommendations related to research and review activities.

Recommendation 3.0: Research and Review needs.

3.1 The Minister of Conservation should review the effectiveness of the new phosphorus-based regulation no later than five years after its coming into force.

3.2 The Department of Conservation should work with other organizations to develop science-based, environmentally and economically sound beneficial management practices for reducing phosphorus losses to surface waters under Manitoba's soil, landscape, and climatic conditions.

Point Sources of Phosphorus

Agricultural point sources or "end of pipe" sources include confined livestock areas, manure storage structures or field storage sites, grazing livestock access to watercourses for drinking water, and seasonal feeding areas. The *Livestock Manure and Mortalities Management Regulation* already requires a 100 metre setback from watercourses for any manure storage structures or field storage sites, as well as confined livestock areas. In addition, livestock in confined areas are prohibited from having direct access to surface watercourses.

While direct access to watercourses by grazing livestock is not specifically prohibited by the *Livestock Manure and Mortalities Management Regulation*, direct discharge of manure in surface water is prohibited. The *Protection of Water Sources Regulation* is used to protect surface water sources of community drinking water.

While these sources of phosphorus are an area of concern, they were not addressed by the Manitoba Expert Phosphorus Committee because existing regulations already address all but direct access by free-ranging livestock.

Appendix A

Specialists and Experts Providing Information to the Committee

(Affiliations, positions and locations listed as at the time of consultation)

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Appendix B

Beneficial Management Practices for Reducing the Risk of Agricultural Phosphorus Loss to Surface Waters

The BMPs listed on the following pages are discussed in terms of how each may have a positive impact on the loading, mobilization, and delivery processes related to phosphorus movement from agricultural land to surface waters. These BMPs are specific to phosphorus management but may not always be consistent with other BMP recommendations for other purposes. The environmental effectiveness of many of these BMPS has not been validated under Manitoba conditions – a critical step in the move toward BMP adoption at the farm-level. In addition, the economic implications of adoption are not included in this document.

BMPs that may reduce loading

Loading is the addition of phosphorus to a given area as a result of imports or inputs. Problems arise when imports exceed exports and a surplus of phosphorus is created. Surpluses can be characterized at various scales – regional, farm-scale, and field level.

Regional Scale Surplus

The potential for surpluses of phosphorus within a region should be minimized by ensuring there is a balance between imports and exports of phosphorus within the region during the land use planning process.

1. *Include phosphorus management plans during the planning stage for new and expanding livestock operations.* For example:
   a) Ensure adequate, suitable land for manure management in order to reduce the potential for farm surpluses of phosphorus.
   b) Where adequate suitable land is not available, demonstrate that the phosphorus can be managed, over the long-term, in another sustainable manner.

Farm Scale Surplus

Surpluses of phosphorus on the farm should be minimized by balancing the import of phosphorus onto the farm with farm exports.

1. *Minimize phosphorus imports onto the farm.*
   a) Minimize supplemental feed phosphorus and maximize overall animal production efficiency. For all livestock operations, reduce the amount of excess phosphorus in the diet by conducting more intensive feed testing, designing farm-specific diets and minimizing insurance additions. In pig production, advanced feed management systems can include phase feeding and split-sex feeding. Feed additives, including enzymes such as phytase, and genetic selection can enable more efficient use of phosphorus fed to pigs and poultry.
   b) Replace fertilizer phosphorus with manure phosphorus for crop production. Manure phosphorus that is applied to a field should be deducted from the crop requirement for phosphorus, thereby reducing the need for additional commercial fertilizer phosphorus.

2. *Maximize phosphorus exports from the farm in farm products.*
   Phosphorus exports from the farm can be maximized by improving overall crop and animal production efficiency. Optimizing the production potential will maximize the amount of phosphorus that leaves the farm in meat, milk and crop products. For example:
   a) Improve overall animal production efficiency. For example, maintain a high health herd status in pig production. Healthy animals are more efficient and therefore utilize more of their ingested nutrients for growth and reproduction rather than for fighting disease.
   b) Improve overall crop production efficiency. One example is to ensure an adequate supply of nitrogen and other nutrients besides phosphorus exists to optimize crop yields and increase the export of phosphorus in harvested products.
   c) Access additional cropland to increase phosphorus exported from the farm in crop yield. Where significant farm phosphorus surpluses exist, additional land may be necessary to increase the amount of manure phosphorus that can be exported as crop yield.

3. *Export manure where necessary*
   Where manure phosphorus quantities exceed the land base available for sustainable application, and additional lands cannot be acquired, manure phosphorus may have to be exported from the farm. This can be a very expensive option, particularly for liquid manures that require hauling of large volumes of water. Options would be to:
   a) Export raw manure from the livestock farm to other nearby farms.
   b) Treat the manure on-farm and export treated manure. Solid-liquid separation is one example of treatment. Concentrating and transporting the phosphorus in the separated solids makes long distance transport more economical.

Field Scale Surplus

Surpluses of phosphorus in the field should be managed by balancing inputs with crop requirements and removals over the long term, while allowing for modest accumulations of soil test phosphorus where it is agronomically desirable and environmentally acceptable over the short term. Field-scale surpluses are most often associated with cropping systems that use manure as a nitrogen fertilizer and high input systems such as potato production. Surpluses of phosphorus in the field, or the build-up of soil test phosphorus, can be managed in a number of ways.

1. *Manage phosphorus inputs to soil from cropland (Nutrient Management).*
   Compared to commercial fertilizer, manure is a dilute source of nutrients, its nutrient composition is variable and it does not contain the same proportions of nitrogen and phosphorus as is removed by crops. Manure is most valuable as a fertilizer when it is applied based on the nitrogen requirements of the crop. However, this often results in the application of more phosphorus than the crop can remove and a build-up of soil test phosphorus. The following BMPs are specific to the land application of phosphorus.

Manure and Commercial Fertilizer

   a) Soil test and account for available soil phosphorus when establishing application rates.
   b) Target phosphorus inputs to achieve realistic target yields.
   c) Optimize fertilizer phosphorus efficiency through proper timing and placement.
      For example, banding inorganic fertilizer in the spring increases the fertilizer efficiency to achieve the same crop response with lower application rates and buries the fertilizer phosphorus below soil surface to reduce risk of runoff loss.
   d) Select fertilizer and manure application equipment and calibrate to optimally distribute nutrients and meet target application rates.
      In the case of liquid manure, narrowly spaced injectors enable better manure distribution than wider spaced systems that must concentrate the same volume of manure in fewer bands.
   e) Do not apply nutrients directly adjacent to surface watercourses.
   f) Maintain comprehensive records to track soil test phosphorus levels, actual yields, etc. in order to adjust nutrient management practices accordingly.

Manure

a) Conserve the nitrogen in manure during storage, handling, and land application to improve the nutrient value and the N:P ratio of the manure.
b) Prioritize lands for manure additions based on soil test phosphorus levels and manure phosphorus concentrations. Solid-liquid separation of manure allows the phosphorus-rich solids to be managed separately from the more dilute liquids. Soils that have lower soil test phosphorus levels should receive the phosphorus-rich solids and the more dilute liquids should be applied to soils with higher soil test phosphorus levels.
c) Rotate lands when manure application is based on nitrogen. Repeated annual applications of manure based on nitrogen have the potential to cause phosphorus build-up. Rotating fields for manure application using a nitrogen-based rate in one year and only commercial nitrogen fertilizer in subsequent years can slow or halt the long-term build-up of soil test phosphorus.
d) Access additional fields for manure application where repeated applications of manure have resulted in excessive soil test phosphorus build-up through purchase, lease, rental or giving manure to a neighbour.

2. *Maximize Phosphorus exports from cropland.*

Maximizing phosphorus exports from the field will also help to slow the buildup of soil test phosphorus over the long-term. BMPs to maximize phosphorus exports from cropland include:

a) Select crops that maximize phosphorus removal. Adjusting crop rotation to include crops that maximize phosphorus removal may be practical only for fields testing high in soil phosphorus. However, long-term rotations that include crops that maximize phosphorus removal should be considered where additional lands for manure spreading are scarce.
b) Select more productive lands to maximize phosphorus removal. Assess the agricultural capability of the land to ensure that the land has the productive capacity to support the targeted yield and manure nutrient application.
c) Maximize crop yield and harvested material removed from the field. Removing as much crop as possible will result in maximum removal of phosphorus from the field (harvesting seed and residue, harvesting forage as hay rather than pasture).

3. *Manage Phosphorus inputs from grazing and over-wintering areas.*

Livestock in outdoor grazing systems and wintering sites also contribute nutrients to the landscape. The following BMPs are intended to reduce the build-up in soil test phosphorus as well as the risk of phosphorus loss from these systems:

a) Manage cattle distribution and density to avoid manure accumulation in any one location, particularly hydrologically active areas (where water flows/accumulates). Low density over-wintering sites should be managed so that the manure is evenly distributed over the landscape. This can be achieved by moving feed, shelter and in some instances, water throughout the field. Practices that increase the grazing season, such as swath grazing, should be designed to avoid accumulation of manure in any given area.
b) Avoid long-term application rates of manure or commercial fertilizer on grazing land that are higher than the net rate of removal by grazing livestock. Most of the forage nutrients consumed by grazing cattle is redeposited in pastures as urine and feces. Therefore, additional nutrient applications to grazing lands should not exceed removal by grazing livestock over the long-term.

4. *Manage Phosphorus export from grazing and over-wintering areas.*
   a) Account for phosphorus on fertilized or manured pasture and periodically harvest forage as hay rather than grazing to increase export of phosphorus.
   b) Remove manure from over-wintering sites where it has accumulated and apply as a fertilizer to cropland.

BMPs that may reduce mobilization

Mobilization occurs on the landscape when conditions are created that start the movement of phosphorus to water by separating the phosphorus from its attachment to the soil. The phosphorus may move as dissolved phosphorus through solubilization, particulate phosphorus through detachment, or directly as fertilizer or manure phosphorus through incidental transfer.

There are a number of BMPs that show promise for reducing mobilization. The most appropriate BMP or combination of BMPs for on-farm adoption will depend on the form of phosphorus being lost from the farm.

1. *Reduce the mobilization of particulate phosphorus (detachment)*
   When soil is transported within a field or from a field, it carries with it a significant amount of phosphorus. Most of that phosphorus is in particulate form. Therefore, controlling soil movement due to water erosion will control the movement of particulate phosphorus.
   a) Identify areas at higher risk of soil erosion. Areas at higher risk of soil erosion can be identified using soil and landscape properties, the Revised Universal Soil Loss Equation (RUSLE), agricultural capability (E subclass), etc.
   b) Minimize the mobilization of particulate phosphorus by controlling soil erosion, particularly in high risk areas. Soil erosion on annual crop land can be minimized by using cover crops, managing residue, reducing tillage operations, and maintaining permanent cover on land with a high risk of soil erosion.

2. *Reduce the mobilization of dissolved phosphorus (solubilization)*
   As soil test phosphorus increases, dissolved (or soluble) phosphorus also increases. Once phosphorus is solubilized, it moves with water and is very difficult to control. Practices that minimize the mobilization of particulate phosphorus, such as no-till crop production, are not effective at controlling soluble phosphorus and may even increase the risk of soluble phosphorus mobilization. The most promising way to reduce the risk of phosphorus loss as soluble phosphorus is by controlling the build-up of soil test phosphorus.
   a) Identify areas at higher risk of solubilization. Areas at higher risk of solubilization could be identified by high soil test phosphorus, poor drainage, inundation during spring snowmelt period, etc. or some combination of these properties. Often P-Indices are developed for this purpose; however there is currently no P-Index for Manitoba.
   b) Minimize the solubilization of soil phosphorus by minimizing buildup of soil test phosphorus through nutrient management planning. See LOADING
   c) Remove high phosphorus plant material from hydrologically active areas.
   d) Where the risk of soil erosion is low and phosphorus stratification is evident with very high soil test phosphorus levels at the surface, use periodic tillage to bury high phosphorus surface soil. This practice is intended to reduce the exposure of soluble phosphorus at the soil surface to runoff but it must be considered carefully within the context of other soil and crop management factors.

3. *Reduce the direct addition of fertilizer or manure phosphorus to water (incidental transfer)*
Incidental transfer of phosphorus is the addition of manure or fertilizer directly into a water flow path. For example, incidental transfer can occur when fertilizer or manure is surface-applied and then is "washed off" of the soil by a rainfall event that exceeds the infiltration capacity of the soil.
   a) Control livestock access to surface water and provide alternate watering.
   b) Inject or incorporate manure to reduce exposure of the manure to rainfall and spring snowmelt in order to minimize incidental transfer.
   c) Band commercial fertilizer below the soil surface to reduce exposure of the fertilizer to rainfall and spring snowmelt in order to minimize incidental transfer.
   d) Eliminate contaminated runoff from winter application. Eliminating the incidental transfer of manure due to winter application may mean banning winter application altogether and, perhaps, late fall applications, as well. This has significant economic consequences for small livestock operations that use liquid manure systems as it would mean increasing the manure storage capacity.
   e) Remove manure from confined areas and apply as a fertilizer to cropland.
   f) Divert clean run-on from open confined areas. Diverting clean run-on from open confined areas minimizes the quantity of contaminated water to manage as runoff from the open confined area.

BMPs that may minimize delivery

Delivery is entry of phosphorus into a surface water pathway. Although phosphorus may have moved within a field or out of a field, it can still be captured before it enters surface water. Capturing the phosphorus before it enters surface water reduces delivery and, ultimately, impact.
BMPs that minimize delivery are practices which can filter or contain phosphorus before it enters surface water or prevent phosphorus from being deposited directly into surface water.

1. *Treat contaminated runoff before it enters surface water.*
   a) Use "Vegetated Buffer Strips" along riparian zones to filter runoff before it enters surface water.
   b) Preserve and/or construct wetlands to treat runoff from agricultural lands.
   c) Vegetate and manage ditches to filter sediment.

2. *Contain and manage contaminated runoff.*
   a) Collect and manage contaminated runoff from open confined areas and solid manure storage piles where necessary.

Notes